Patent Application

of

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for

See-Saw Interconnect Assembly with Dielectric Carrier Grid Providing Spring Suspension

FIELD OF INVENTION

The present invention relates to Interconnect assemblies for repetitively establishing conductive contact between opposing contact arrays. Particularly, the present invention relates to interconnect assemblies having a number of arrayed interconnect stages including see-saw interconnects embedded in a spring force providing dielectric carrier structure.

BACKGROUND OF INVENTION

Demand for ever decreasing chip fabrication costs forces the industry to develop new solutions for inexpensive and reliable chip testing devices. A common component for

repetitively contacting contact arrays of tested circuit chips is an interconnect assembly that is placed adjacent a test apparatus contact array that has contact pitch corresponding to the tested chips' carrier (package) contact pitch. During packaged chip testing, a package is brought with its contact array into contact with the interconnect assembly such that an independent conductive contact is established between each of the package's contacts and the corresponding contact of the test apparatus.

Interconnect arrays have to provide highly uniform contact resistance over a desirably large deflection range to reduce degrading measurement influences of dimensional test contact variations. With decreasing contact pitches and increasing numbers of test contacts of packaged chips, it becomes increasingly challenging to design interconnect arrays that can be fabricated with low fabrication costs while meeting the demand for maximum deflection with an ever decreasing footprint available for each interconnect stage. The present invention meets this challenge.

Further desirable characteristics of an interconnect array are minimum path lengths and complexity of the individual conductive paths within the interconnect array to improve electrical performance and minimal overall contact force necessary to reliably establish all required conductive paths across the interconnect array. These characteristics become increasingly important as test frequencies and number of conductive paths within a single interconnect array increase. The present invention addresses these needs.

Each individual interconnect has to provide a maximum deflection within a given footprint commonly defined by the contact pitch. At the same time, each interconnect has to provide sufficient structural stiffness to warrant sufficient scribing in the interface between contact tips of the interconnects and the respective contacts of the package's contacts. In the prior art, planar arrayed interconnects have been fabricated with varying shapes, commonly embedded in substantially rigid dielectric carrier structures or carrier frames. For example, interconnects have been fabricated as see-saw structures integrated with torsion beams or torsion bridges that assist in increasing the interconnects' overall deflection. The interconnects are embedded thereby in the carrier structure such that the carrier structure remains structurally substantially unaffected by the interconnects deflections. Spring loaded deflection and wear resistant contacting features are provided by the same monolithic structure. This poses a significant limitation on maximizing deflection range due to the opposing material requirements for stiffness of the contacting features and resilience of the spring features. In the present invention addresses this problem.

For a cost effective and reliable fabrication of interconnect assemblies there exists a need for a interconnect configuration that requires a minimum number of involved fabrication steps and individual components. Fabrication steps are preferably performed along a single axis. Assembling operations are preferably avoided. The present invention addresses this need.

SUMMARY OF THE INVENTION

An interconnect assembly includes a number of conductive and relatively stiff interconnect structures combined in a preferably planar dielectric carrier grid that has relatively resilient portions. The resilient portions act as spring members that resiliently deform upon the interconnects' displacement that takes place when a packaged chip is brought into contact with the interconnect assembly.

Each interconnect structure is fabricated and combined with the carrier grid for performing a see-saw pivoting movement around a rotation axis that substantially coincides with a symmetry plane of torsion features that are part of the resilient portions. The torsion features protrude laterally towards and adhere to a central portion of the see-saw interconnect such that an angular movement of the interconnect is resiliently opposed by the torsion feature and the remainder of the resilient portions. The resilient portions and interconnects may be independently optimized to provide the interconnects with maximum deflection stiffness, wear resistance, and conductivity.

Contacts of the test apparatus are in an offset to the test contacts. The substantially rotationally symmetric configuration of each see-saw interconnect with respect to its respective pivot axis results mainly in a torque that needs to be opposed by the respective resilient portion. A symmetric configuration of the resilient portion results in a balanced counteracting torque such that the overall

position of the interconnects remains highly unaffected during the interconnects' displacement.

Each see-saw interconnect features at least one contact tip at each of the interconnects' opposing ends. The interconnect may be configured for multipath current transmission.

The initial contact force of the tips may be tuned by adjusting the angle of the sew-saw interconnect with respect to the approach direction of the test contacts. This may be utilized to improve the tips' scribing on the test pads.

BRIEF DESCRIPTION OF THE FIGURES

The file of this patent contains Figures 12 - 18 executed in color. Copies of this patent with color drawings will be provided by the Patent and Trademark Office upon request and payment of the necessary fee.

Fig. 1 is a perspective top view of an interconnect assembly in accordance with a first embodiment of the present invention.

Fig. 2 illustrates a bottom view of the assembly of **Fig. 1**.

Fig. 3 depicts a cut view of the assembly of **Fig. 1** as indicated in **Fig. 2** by the section line **A-A**.

Fig. 4A, 4B, 4C are detail views of **Fig. 2** showing various exemplary configurations of a see-saw interconnect structure.

Fig. 5A, 5B, 5C are detail views of **Fig. 2** showing various exemplary configurations of an interface between an interconnect structure and a torsion feature.

Fig. 6 is a detail view of **Fig. 2** centering on an outlined exemplary resilient portion.

Fig. 7 shows an exemplary stress analysis of the resilient portion of **Fig. 6**

Fig. 8 shows an exemplary displacement analysis of the resilient portion of **Fig. 6**

Fig. 9 is a graph of deflection over load for an exemplary interconnect stage according to **Figs. 1 - 3, 4B, 5A.**

Fig. 10 is a graph of resistance over current flow for an exemplary interconnect stage according to **Figs. 1 - 3, 4B, 5A.**

Fig. 11 is a block diagram of exemplary fabrication steps involved in making the interconnect assembly of **Figs. 1 - 3.**

DETAILED DESCRIPTION

In the following the terms "horizontal, vertical, upwards, downwards, bottom, top, X-oriented, Y-oriented" are used in conjunction with the Figures. As it may be clear to anyone skilled in the art, these terms are used solely for the purpose of ease of understanding and to describe spatial relations of elements with respect to each other.

Figs. 1, 2 show an interconnect assembly **1** that includes a horizontal dielectric film **2** circumferentially adhering to a support frame **4** via a grid flange **22**. Shaped in the dielectric film **2** is a carrier grid **21**, which may have X-oriented grid members **212** and Y-oriented grid members **211** that connect in the grid nodes **213**. On centered locations of the Y-oriented grid members **211** adhere electrically conductive see-saw structures **3**. Preferably each of the see saw structures **3** has a planar central portion **32** that overlaps with an interface portion **214** of the grid members **211**. The see-saw structures **3** are connected to the carrier grid **21** via the interface portion **214**. The interconnect assembly **1** may have alignment features **11** well known for precision positioning the interconnect assembly **1** in a larger device such as a well known probe apparatus **100** a portion of which can be seen in **Fig. 3**.

Preferably each of the conductive see-saw structures **3** is substantially symmetric with respect to a symmetry plane **SP**, which is in vertical orientation and in the middle between two X-oriented grid members **212**. A first peripheral arm **31** extends laterally downwards from the planar center portion **32** along the symmetry plane **SP** and terminates in a first contact tip **35**. A second peripheral

arm **33** extends laterally upwards from the planar center portion **32** in opposite direction of the first peripheral arm **31** also along the symmetry plane **SP**. The second peripheral arm **33** terminates in a second contact tip **36**. The see-saw structures **3** are preferably sheet metal like structures preferably made with well-known electro deposition techniques in conjunction with a 3D forming operation.

The see-saw structures **3** are preferably two dimensionally arrayed within the interconnect assembly **1** such that the first tips **35** comply with a first contact pattern defined by a first X-pitch **PX1** and a first Y-pitch **PY1**. Accordingly, the second tips **36** comply with a second contact pattern defined by a second X-pitch **PX1** and a second Y-pitch **PY2**. In the preferred embodiment, all see-saw structures **3** are arrayed in parallel and have substantially equal shape and scale such that the first contact pattern is in a tip offset **O1** to the second contact pattern but otherwise substantially equal. The tip offset **O1** is defined by the horizontal distance between the contact tips **35, 36** along the symmetry plane **SP** of a common see-saw structure **32**.

The present invention may include embodiments, in which the see-saw structures **3** are shaped, positioned and/or oriented for defining first and second contact patterns that differ from each other. This may be of particular advantage, where the interconnect assembly **1** is a modular part of a probe apparatus **100** as shown in **Fig. 3**. In such a probe apparatus **100**, apparatus contacts **102** may be provided by a contact base **101** with a fixed first contact pattern. A

variety of interconnect assemblies **1** may be interchangeably utilized to adjust to tested devices **TD** having varying second contact pattern of test contacts **TC**.

The carrier grid **21** provides resilient features such as torsion features **215** and optionally flex features **216** (see **Fig. 6**) that resiliently deform and oppose a displacement of the see-saw structures **3** in operational contact with test contacts **TC** and apparatus contacts **102**. In a first load case the see-saw structures' **3** displacement is substantially a rotational displacement around a rotation axis **RA**, which is preferably perpendicular to the symmetry plane **SP**. Rotational displacement takes place, when both groups of apparatus contacts **102** and/or test contacts **TC** are forced against their corresponding contact tips **35, 36** in a balanced fashion resulting in a torque induced on the see-saw structures **3** due to the horizontal distances **DH1, DH2** of the contact tips **35, 36** relative to the rotation axes **RA**.

In a second load case, where only one group of the apparatus contacts **102** or test contacts **TC** is forced against their corresponding tips **35** or **36** or where the opposing forces experienced by corresponding contact tips **35, 36** are not fully balanced, the resilient features also resiliently oppose a substantially vertical displacement of the see-saw structures **3**.

In an exemplary application, the interconnect assembly **1** may be assembled in the probe apparatus **100** such that the contact tips **35** are in permanent pressure contact with their respective apparatus contacts **102**. At the time

between test cycles, where no tested device **TD** is forced against the contact tips **36**, the second load case is experienced by the interconnect assembly **1**. At the time a tested device **TD** is placed in a test position relative to the probe apparatus **100**, the first load case is experienced by the interconnect assembly **1**.

The contact forces experienced by the contact tips **35, 36** result mainly from the resilient properties of the resilient features in conjunction with a displacement of the contact tips **35, 36** along their respective apparatus contact axes **CA** and test contact axes **TA**. The tip's **35, 36** displacements are induced by the corresponding contacts **102, TC**. The see-saw structures **3** are preferably configured as substantially rigid elements relative to the resilient features, even though some resilient deformation may also occur in the see-saw structures **3**.

Each see saw structure **3** and its corresponding resilient features **215, 216** define an interconnect stage that is preferably configured to balance opposing contact forces resulting from substantially equal displacements induced on both contact tips **35, 36**. The preferred interconnect stage configuration includes a rotationally symmetric configuration of the see-saw structure **3** with respect to the rotation axis **RA**. The preferred interconnect stage configuration includes also a rotationally symmetric configuration of the resilient features **215, 216** with respect to the rotation axis **RA**.

The rotationally symmetric configuration of the resilient features **215, 216** includes substantially rotationally

symmetric shapes of the resilient features **215, 216** with respect to the rotation axis **RA** and substantially rotationally symmetric boundary conditions of the resilient features **215, 216** as may be well appreciated by anyone skilled in the art.

The rotationally symmetric configuration of the see-saw structure **3** includes the planar central portion **32** horizontally evenly extending around an intersection between the symmetry plane **SP** and the rotation axis **RA** as well as substantially equal horizontal distances **DH1, DH2** and vertical distance **CT, CB** of the contact tips **35, 36** relative to the rotation axis **RA**.

For a given size of the central portion **32,** the positions of the contact tips **35, 36** relative to the rotation axis **RA** and the dielectric film **2** is mainly defined by a length of the peripheral arms **31, 35** and their respective bending angles **BA1, BA2**. The vertical distances **CT, CB** may be selected for sufficient clearance between the contacts **TC, 102** and elements of the interconnect assembly **1** under operational conditions. A first proportion between distances **DH1** and **CT** as well as a second proportion between distances **DH2** and **CB** may be adjusted to vary a scribing motion of the contact tips **35, 36** on their corresponding contacts **TC, 102** as may be well appreciated by anyone skilled in the art.

Since the spring suspension of the interconnect stages is provided by the resilient features **215, 216,** the see-saw structures **3** may be configured and optimized mainly for transmitting an electrical current and/or voltage with

minimum resistance between a test contact **TC** and a corresponding probe apparatus contact **102**. **Figs. 4A-4C** depict exemplarily configured see-saw structures **3A-3C**.

In **Fig 4A**, an exemplary see-saw structure **3A** provides a single conductive path between the contact tips **35, 36**. In **Fig. 4B**, an exemplary see-saw structure **3B** features slots **38** that propagate from the contact tip segments **351, 352, 361, 362** towards the center of the see-saw structure **3B** separating arm segments **311, 312, 331, 332**, and optionally some of the central portion **32**. Increasing the number of arm segments **311, 312, 331, 332** and the number of contact tip segments **351, 352, 361, 362** provides for some flexibility of the see-saw structure **3B** to compensate for eventual shape irregularities of the contacts **TC, 102** and eventually leverages contact resistance discrepancies between adjacent contact tip segments **351, 352** and **361, 362**.

In **Fig. 4C**, an exemplary see-saw structure **3C** features two entities **301, 302** conductively separated by the slot **38** continuously propagating between the opposing tip segments **351, 352**, and **361, 362**. The see-saw structure **3C** provides a dual path connection between a single set of corresponding contacts **TC** and **102**. As may be well appreciated by anyone skilled in the art, more than a single slot **38** may be utilized to provide a partial or full multipath connection between opposing contacts **TC** and **102** in a number larger than two.

The mechanical interface between see-saw structures **3, 3A, 3B, 3C** and the carrier grid **21** has significant influence on

the current flow limitations across the see-saw structures **3, 3A, 3B, 3C**. This is because temperature rise that results from current flow tends to degrade the mechanical connection between the see-saw structure **3, 3A, 3B, 3C** and the interface portion **214**. In the exemplary case of an adhesive connection between planar center portion **32** and interface portion **214**, the adhesive strength degrades with increasing temperature. On the other hand at a final fabrication stage where the see-saw structure **3, 3A, 3B, 3C** is already combined with the carrier grid **21**, the 3D forming of the see-saw structure **3, 3A, 3B, 3C**, may require clearance areas **CL** on both sides of the planar center portion **32** immediately adjacent the bending edges **34, 37**. The clearance areas **CL** provide direct access for a clamping tool eventually necessary for fixedly holding the planar center portion **32** during the 3D forming of the peripheral arms **31, 35** and/or the arm segments **311, 312, 351, 352**. This case is depicted in **Fig. 5A**, where the interface portion **214** has an interface length **2141** that corresponds to the planar center portion's **32** width and an interface width **2142** that corresponds to the torsion features' width **2152**. In that case, the Y-oriented grid member **211** has a continuous width between the grid nodes **213**.

In the embodiment depicted in **Fig. 5A**, shear peak points **203** are located at the intersections between the boundaries of the Y-oriented grid member and the planar center portion **32**. In the embodiment of **Fig. 5A**, the shear peak points **203** and delamination origins **204** coincide as may be well appreciated by anyone skilled in the art. The delamination origins **204** are those points where a delamination between

interface portion **214** and planar center portion **32** initiates with high probability.

In an alternate embodiment shown in **Fig. 5B,** the interface portion **214** has a modified interface width **2142B** that is substantially larger than the torque feature width **2152.** As a favorable result, the delamination origins **204** are in a substantially larger distance to the rotation axis **RA** than the shear peak points **203.** In this embodiment and for a given peak shear stress in the shear peak points **203,** the adhesive strength may be brought to lower levels than in the embodiment of **Fig. 5A.** Consequently, the see-saw structure **3, 3A, 3B, 3C** may be operated at increased temperatures during increased current flow.

In a further embodiment shown in **Fig. 5C,** the interface portion **214** may be sandwiched between the planar center portion **32** and a stiffening structure **401.** The stiffening structure **401** may be coplanar with the circumferential support frame **4** and may be a remainder after shaping and releasing the carrier grid **22** during fabrication of the interconnect assembly **1** as is explained in more detail in the below. The stiffening structure **401** may assist in increasing the overall stiffness of the see-saw structure **3, 3A, 3B, 3C** especially in the case where a number of conductively separated entities **301, 302** are utilized for multipath current transmission.

In the enlarged detail view of **Fig. 6,** the torque features **215** and flex features **216** are shown within their envelope **2X, 2Y.** The Y-extension of the envelope is defined as the lateral distance between adjacent see-saw structures **3, 3A,**

3B, 3C. The X-extension **2X** of the envelope extends between zero torque boundaries of adjacent flex features **216A** and **216B**. The zero torque boundary is the line along which the opposing torques of the adjacent flex features **216A, 216B** balance each other as may be well appreciated by anyone skilled in the art.

In the preferred embodiment and as shown in the Figs. **1-3** with a homogeneous carrier grid **21** and a homogeneous array of symmetrically configured resilient features **215, 216,** the zero torque boundary may be at the same time be a zero displacement boundary as may be well appreciated by anyone skilled in the art. As a favorable result, strain and displacement in each of the interconnect stages' resilient features **215, 216** is highly uniform resulting in consistent contacting properties of all interconnect stages of the interconnect assembly **1** while keeping the carrier grid 21 free of any interposed rigid structures. This again provides a maximum available footprint for each of the see-saw structures **3, 3A, 3B, 3C** and a highly efficient, robust and wear resistant operation of the interconnect assembly **1**.

The exemplary stress and displacement analyses of **Figs. 7, 8** illustrate maximum stress and displacement for the resilient features **213, 216** within the envelope **2X, 2Y**. Stress and displacement distribution corresponds to the color array included in the Figures with the minima being depicted in dark blue and the maxima being depicted in red.

The graph of **Fig. 9** shows the deflection over load for an exemplary interconnect stage according to **Figs. 1-3, 4B, 5A**

having pitches **PX1, PX2,** of approximately 1.22mm and pitches **PY1, PY2** of approximately 1.27mm. The offset **O1** is about 1.04mm. The material of the see-saw structure **3** is NiMn alloy electro plated with a thickness of preferably about between 0.02 - 0.03mm. The thin film **2** is made of polyimide with a thickness of about 0.04mm. The width of the grid members **211, 212** is about 0.2mm.

The graph of **Fig. 10** shows two trial curves for transmission resistance over current flow for an exemplary interconnect stage according to **Figs. 1-3, 4B, 5A.** As can be seen in curve of the torsion trial 1, the transmission resistance increases substantially at about 1.5A current flow and about 0.04 mOhms. This indicates a temperature rise to a level where the bonding strength of the adhesive decreases below the shear stress in the delamination origins **204**. Consequently, dilamination is initiated relusting in a reduced displacement of the resilient features **215, 216** and a corresponding decrease of the opposing spring force provided by the resilient features **215, 216**. This in turn reduces the contact pressure and well known scribing between the contact tip segments **311, 312, 331, 332** and their corresponding contacts **TC, 102** such that the contact resistance in the interface between the contact tip segments **311, 312, 331, 332** and their corresponding contacts **TC, 102** gradually increases.

Fabrication of interconnect assembly **1** includes well known fabrication steps summarized in **Fig. 10**. The block **1001** represents the fabrication of the see-saw structures **3, 3A, 3B, 3C** in conductively combined arrangement that corresponds to their final arrangement within the

interconnect assembly **1**. The involved steps may include well known patterning and electroplating of a planar layout of the see-saw structures **3, 3A, 3B, 3C** preferably on top of a sacrificial stainless steel substrate.

The block **1002** represents the fabrication of the carrier grid **21** together with the circumferential support frame **4** and eventual stiffening structures **401**. A dielectric thin film **2** deposited on a substrate is patterned and shaped. The dielectric thin film **2** is preferably made of a polymer such polyimide. The substrate may be stainless steel or any other suitable material as may be appreciated by anyone skilled in the art. The carrier grid **21** is preferably a dielectric laminate that is laminated to the conductive layer and consecutively released by removing the underneath substrate except the eventually stiffening structures **401**, which may be altered in thickness by a separate material removal process.

According to block **1003**, the prefabricated and conductively connected see-saw structures **3, 3A, 3B, 3C** are combined with the previously fabricated carrier grid by adhesive bonding or other well known techniques for combining a metal structure with a polymer. In following steps depicted by blocks **1004, 1005** and **1006**, the see-saw structures **3, 3A, 3B, 3C** may be lasered and electro plated, 3D formed and released from their conductive connection by well known techniques. The conductive connection is a particular necessity in case of electro deposition processes utilized in combination with a dielectric carrier grid **21** to include all see-saw structures **3, 3A, 3B, 3C** in

a single electric connection for efficient simultaneous plating as is well known to anyone skilled in the art.

The scope of the invention is not limited to a particular outside contour of the see-saw structures **3, 3A, 3B, 3C** as long as their function is warranted as described in the above. Likewise, the scope of the invention is not limited by a particular fashion by which the interconnect stages are arrayed within an interconnect assembly as may be well appreciated by anyone skilled in the art.

Accordingly, the scope of the invention described in the above specification is set forth by the following claims and their legal equivalents: